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(71) Applicant:
**TOSHIBA LIGHTING & TECHNOLOGY CORPORATION**
**Shinagawa-ku, Tokyo 140-8640 (JP)**

(72) Inventors:
- **TAKAHARA, Yuichiro**
  **Yokosuka-shi, Kanagawa-ken 239-0826 (JP)**
- **MISONO, Katsuhide**
  **Yokohama-shi, Kanagawa-ken 233-0015 (JP)**
- **WATANABE, Akio**
  **Yokohama-shi, Kanagawa-ken 245-0003 (JP)**

(74) Representative:
**Litchfield, Laura Marie**
**Haseltine Lake & Co.**
**Imperial House**
**15-19 Kingsway**
**London WC2B 6UD (GB)**

## (54) ELECTRODE STRUCTURE FOR ELECTRON EMISSION, DISCHARGE LAMP, AND DISCHARGE LAMP APPARATUS

(57) This is an electron emission electrode structure that can shorten the transition time from glow discharge to arc discharge and, at the same time, stabilise the arc discharge and prevent reduction of electrode life and blackening of the tube inner wall, together with a discharge lamp that uses this electrode structure and a discharge lamp device in which this discharge lamp is installed.

It is electron emission electrode structure **3A** that is composed of electron emitter **5**, made of an aggregate of granules **51**, ..., that emits thermal electrons from an exposed surface when heated by a discharge, and a discharge focussing means that is in the close vicinity of, or in contact with, the above exposed surface of electron emitter **5** and focuses the discharge on the above exposed surface, together with discharge lamp **1** that uses electrode structure **3A** and discharge lamp device **9** in which discharge lamp **1** is installed.

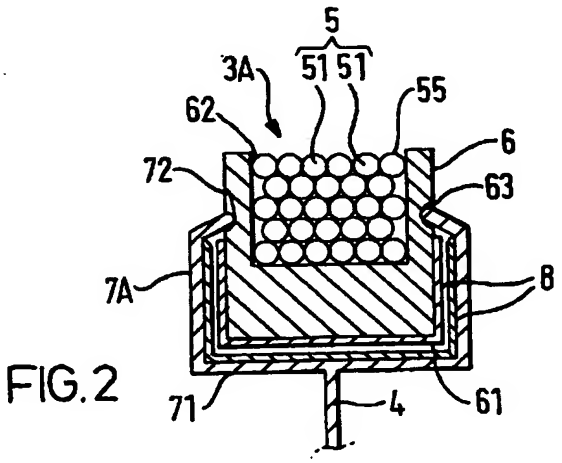


FIG. 2

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## Description

### FIELD OF THE INVENTION

[0001] The present invention relates to electron emission electrode structures designed for long life, discharge lamps and discharge lamp devices.

### BACKGROUND OF THE INVENTION

[0002] Electron emission electrodes for discharge lamps may be broadly divided into hot cathodes and cold cathodes. Of these, electrodes in which oxides of transition metals and alkaline earth metals, including barium, are coated on filament coils of tungsten, for example, are often used as hot cathodes.

[0003] Also, electrodes in which electron emitters, including barium tungstate, are impregnated into porous tungsten, for example, are known as other hot cathodes.

[0004] At the same time, resource-saving and energy-saving have been promoted in recent years. Therefore, higher efficiency and capillarisation (miniaturisation) of tubes have been devised for the discharge lamps for back-lighting installed in OA equipment, such as facsimile machines, and image equipment, such as liquid crystal television, not to speak of discharge lamps for general-purpose lighting, such as fluorescent lamps. In addition, the demand for these has increased.

[0005] However, of the above-mentioned hot cathodes, with the former, the filament coil electrodes, the filament length became shorter as the tube was miniaturised. Therefore, large quantities of electron emitters could not be maintained, and, as well as being unable to obtain a satisfactorily long life, there was little strength against vibration because of the fine wire.

[0006] Also, although the latter, the porous tungsten electrodes, are used in large current type high-pressure discharge lamps, such electrodes are difficult to produce. Moreover, in the small current domain of low-pressure discharge lamps, such as fluorescent lamps, there were problems such as their not operating stably as hot cathodes.

[0007] In this way, it was not possible to design capillarisation of discharge lamp tubes with the hot cathodes mentioned above. Therefore, cold cathodes made of metals such as nickel or aluminium-zirconium alloy were used. However, there were large cathode drop losses with these cold cathodes, and large lamp currents could not be achieved.

[0008] Therefore, as a means of designing discharge lamp miniaturisation and at the same time obtaining large lamp currents, the electrode structure stated in Laid-Open Patent Heisei 1-65764 Gazette, for example, was developed. In this Laid-Open Patent Heisei 1-65764 Gazette, a hot cathode was described in which the thermal electron emission portion was formed by semiconductor ceramic particles in a container that was shaped as a cylinder having a bottom and of which the front side was open.

[0009] Also, according to the description in this Gazette, by making the thermal electron emission part a particulate, the heat capacity of the thermal electron emission part became lower than that of the container. Thus, during glow discharge, the temperature rise of the thermal electron emission part was rapid, and transition to arc discharge was accelerated by making thermal electron emission easier. In this case, because a greater current density can be obtained, the discharge lamp tube can be capillarised by making the external diameter of the electrode smaller.

[0010] However, with the semiconductor ceramic of the thermal electron emission part described in this Laid-Open Patent Heisei 1-65764 Gazette, the thermal electron emission part does not reach the specified temperature during glow discharge for reasons such as insufficient activation of the surface. Therefore, sometimes an arc spot is not formed on the thermal electron emission part, and the discharge surrounds the periphery of the container. Then, if the discharge surrounds the container, the inner wall of the discharge lamp becomes blackened due to the high cathode fall voltage, and the electrode life is shortened. In particular, if the thermal electron emission capability of the thermal electron emission part is reduced, surrounding by the discharge will occur more readily before the life of the electrode has run out, and the shortening of life will be accelerated.

[0011] Also, for example, according to Laid-Open Patent Heisei 6-302297 Gazette and National Publication Patent Heisei 9-507956 Gazette, the hot cathode may be held in a holder. This holder is connected to lead wires for supplying current that are led to the outside of the discharge lamp.

[0012] During glow discharge, the holder plays the role of a cold cathode and the electron are supplied by the secondary emmision. When the temperature rises during glow discharge, thermal electron emission from the semiconductor ceramic dominates over the second emmision, and transition to arc discharge takes place.

[0013] However, with these structures stated in these Laid-Open Patent Heisei 6-302297 Gazette and Published Patent Heisei 9-507956 Gazette, the temperature of the thermal electron emission part is difficult to rise during glow discharge, and it takes some time before transition to arc discharge. Also, if the glow discharge time is long, trouble will occur with the hot cathode because the cold cathode will undergo a large sputtering effect. That is to say, the active substance on the surface of the semiconductor ceramic will be sputtered. Sputtered substances from the container and

the inner leads will accumulate on the surface of the semiconductor ceramic, and, because the work function will become higher, the disadvantage of reduction of the thermal electron emission capability will occur. This will cause reduction of the electrode life and blackening of the inner wall of the discharge lamp tube.

**[0014]** As stated above, with the semiconductor ceramic of the thermal electron emission part described in Laid-open Patent Heisei 1-65764 Gazette, for reasons such as insufficient activation of the surface, the thermal electron emission part does not reach the specified temperature during glow discharge. Therefore, sometimes an arc spot is not formed on the thermal electron emission part, and the discharge readily surrounds the periphery of the container. Then, if the discharge surrounds the container, the inner wall of the discharge lamp tube becomes blackened due to the high cathode fall voltage, and the electrode life is shortened.

**[0015]** Also, with the structures described in these Laid-Open Patent Heisei 6-302297 Gazette and Published Patent Heisei 9-507956 Gazette, the temperature of the thermal electron emission part is difficult to rise during glow discharge, and it takes some time before transition to arc discharge. Also, if the glow discharge time is long, trouble will occur with the hot cathode because the cold cathode will undergo a large sputtering effect.

**[0016]** That is to say, there is the problem that the active substance on the surface of the semiconductor ceramic will be sputtered. Sputter substances from the container and the inner leads will accumulate on the surface of the semiconductor ceramic, and the disadvantage will occur of the work function becoming higher and causing reduction of the thermal electron emission capability. This will cause reduction of the electrode life and blackening of the inner wall of the discharge lamp tube.

**[0017]** The present invention has been devised in the light of the above problems. Its purpose is to provide electron emission electrode structures that shorten the time for transition from glow discharge to arc discharge and, at the same time, can stabilise the arc discharge and can prevent electrode life reduction and lamp inner wall blackening, discharge lamps that use these electrode structures and lamp devices in which these discharge lamps are installed.

## DISCLOSURE OF THE INVENTION

**[0018]** The present invention provides the inventions in the following numbered sections.

(1) An electron emission electrode structure comprising: an electron emitter heated by a discharge, composed of an aggregate of electron emission granules, and emitting thermal electrons from an exposed surface
and
a discharge focussing means which is in the close vicinity of, or in contact with, at least a part of the exposed surface of this electron emitter and focuses the discharge on the exposed surface.

This thermal electron emission electrode comprises an aggregate of granules. On starting, the exposed surface of this aggregate surface produces a glow discharge as a cold cathode, and the temperature is raised by ions, accelerated by the high cathode fall voltage, heating the whole of the electrode. The temperature rises readily since, in addition to the heat capacities of the particles of the electron emitter being small, the thermal resistance between adjacent particles is also high. After this, when the temperature at which sufficient thermal electrons can be emitted is reached by the concentrated heating of the particles, transition from glow discharge to arc discharge takes place.

That is to say, by providing a discharge focuser, the electrical field can be focused on at least a part of the exposed surface of the electron emitter, composed of an aggregate of granules, at the time of glow discharge. Thus, the temperature of the electron emitter can be raised in a short time.

(2) An electron emission electrode structure comprising:

an electron emitter heated by a discharge, composed of an aggregate of particles or granules, which emits thermal electrons from an exposed surface;
a discharge focussing means which is in the close vicinity of, or in contact with, at least a part of the exposed surface of this electron emitter and focuses the discharge on that exposed surface
and
a container housing the electron emitter.

Then, by making the container itself a conductor when the container is of a conductive material, or by providing a conductor, separate from the container, in the close vicinity of the electron emitter inside the container when the container is of insulating or semi-insulating material, the electrical field can be focused on the conductor during glow discharge.

Thus, the arc discharge will occur on the exposed surface of the electron emitter surface facing the open part of the container.

Also, the arc spot can be formed quickly and stably by raising the temperature of the electron emitter in a short

time. Thus, when this electrode is used in a discharge lamp, by accelerating the transition from glow discharge to arc discharge, there will be no blackening of the inner wall of the tube and the life will be elongated.

(3) An electron emission electrode structure that has the characteristic of being composed of:

an electron-emitter, composed of an aggregate of granules, that is heated by a discharge and emits thermal electrons from an exposed surface
and
a container that houses this electron emitter, and focuses the discharge on the exposed surface of the electron emitter by making a part that is in the close vicinity of, or in contact with, at least one part of that exposed surface a conductor.

(4) An electron emission electrode structure, as in (3), that has the characteristic of the container being made of metal.

The material of the container is composed of at least one metal that has a comparatively low vapour pressure, even at the temperature reached by the electrode during discharge, such as, for example, W, Mo, Re, Ta, Ti, Zr, Ni or Fe, or of alloys of these metals, or of the carbides, C, the nitrides, N, the silicides, Si, or the borides, B, of these metals. Also, when switched ON, these substances act as good conductors and satisfactorily perform the passage of current to the electron emitters housed inside. Thus, arc spots are readily formed, and good electron emission is obtained.

Also, semiconductor substances composed of the oxides of Ba, Sr, Ca, Th, etc., may be added to the above metals. These containers have smaller thermal capacities than those formed entirely of metals, while at the same time, it is difficult for the heat to escape. Thus, arc spots will readily form on the electron emitter granules.

(5) An electron emission electrode structure, as in (4), that has the characteristic of the outer surface of the metal container having an insulating coating.

Discharge from the part with the insulating coating is difficult. The electrical field focuses on the part where the metal is exposed, and a glow discharge can be generated focused on the exposed surface part of the electron emitter. The insulating coating can be formed using at least one metal oxide, such as aluminium oxide, silicon oxide, zirconium oxide or tantalum oxide, or of mixtures of these.

(6) An electron emission electrode structure, as in (2), that has the characteristic of the container being insulating or semi-insulating.

(7) An electron emission electrode structure, according to (6), that has the characteristic of the container being composed of metal oxide.

With (6) and (7), the container is a semi-insulating, for example, semiconductor ceramic obtained by adding an additive (such as $Ta_2O_3$) to a mother crystal (such as $BaTiO_3$ or $BaZrO_3$). This container does not have good conductivity at normal temperature but, as the temperature rises, its resistivity decreases and it becomes a good conductor. Then, once it has become a conductor, the temperature of the container becomes high and continues to maintain the discharge by stimulating activation of the electron emitter housed in the container.

Also, in the case of a highly insulating container, a conductive metal plate or coating made of a film of metal carbide, metal nitride, etc. may be provided on the surface of the container so that electrical connection with the electron emitter housed in the container is established.

(8) Any electron emission electrode structure, as in (2) to (7), that has the characteristic of the container being supported in a holder.

(9) An electron emission electrode structure, as in (1), in which the discharge focusing means is a metal lug that is in the close vicinity of, or in contact with, at least a part of the exposed surface of the electron emitter.

By making the tip of a rod-shaped or plate-shaped metal lug sharp, the electrical field near this portion becomes even more enhanced during glow discharge. It is desirable to make the sharp part of this tip a shape that will produce electrical field focusing, including making the tip such shapes as a sharp needle shape, angular, conical or pyramidal, or such shapes as a truncated cone, a truncated pyramid or an arc.

In the case when the container is conductive and a conductor is provided separately from the container, it is desirable that the two should be electrically connected so that they are of the same potential.

(10) An electron emission electrode structure, as in (9), that has the characteristic of the metal lug being tongue-shaped.

(11) An electron emission electrode structure, as in (1), that has the characteristic of the discharge focusing means being a conductive rod-shaped lug that passes through the electron emitter and protrudes from the exposed surface.

(12) An electron emission electrode structure, according to (10), that has the characteristic of the rod-shaped lug protruding from the centre of the exposed surface.

(13) An electron emission electrode structure, according to (11), that has the characteristic of the rod-shaped lug

protruding off-set from the centre of the exposed surface.

By the protruding rod-shaped lug protruding from a position displaced from the central axis of the exposed surface of the electron emitter, the temperatures of the electron emitter in contact with, or in the close vicinity of, the container inner wall and the periphery of the protruding part, where arc spots readily form, rise more rapidly. Thus, transition from glow discharge to arc discharge can be improved.

(14) An electron emission electrode structure, as in (2), that has the characteristic of the discharge focusing means being a metal mesh that covers the open part of the container.

By providing a conductor composed of metal mesh facing the exposed surface of the electron emitter on the open part of the container front surface, the temperature of the electron emitter can be raised and the arc spot can be caused to form, since the electrical field is focused by the mesh during glow discharge. Thus, the transition to arc discharge during glow discharge is accelerated, and when this electrode is used in a discharge lamp, there is no blackening of the tube inner wall, nor shortening of life.

For this mesh, either a mesh woven from metal wire, such as Ni, W or stainless steel, or a mesh formed by punching multiple holes in a metal plate, can be used.

(15) An electron emission electrode structure, according to any of (9) to (13), that has the characteristic of the discharge focusing means being formed in the container or in the holder.

(16) An electron emission electrode structure, as in (1) or (2), that has the characteristic of the granules of the electron emitter being formed mainly of the oxide of at least one alkaline earth metal, transition metal or rare earth metal.

It is desirable that the granular particles of the electron emitter should be formed mainly of the oxide of at least one alkaline earth metal, transition metal or rare earth metal.

As formation materials, for example, materials composed mainly of alkaline earth metals with metal oxides, such as BaO, SrO, CaO and $Ba_4Ti_2O_9$, $BaTaO_3$, $SrTiO_3$, $SrZrO_3$, and materials composed mainly of alkaline earth metals with oxides of rare earth (such as Sc, Y, La and lanthanide) metals, such as $BaCeO_3$, can be used.

Also, these having low work functions, their cathode drop losses are small. Moreover, since they do not react readily with components of the atmosphere, they exhibit actions such as ease of manufacture.

(17) An electron emission electrode structure, as in (1) or (2), that has the characteristic of a film of a carbide and/or a nitride of at least one alkaline earth metal, transition metal or rare earth metal being formed on the surface of the granules of the electron emitter.

As the films, composed of a carbide and/or a nitride of at least one alkaline earth metal, transition metal or rare earth metal, that are the films formed on at least a part of the surface of the granules of the electron emitter, the carbides and nitrides of such as Ti, Ta, Zr, Nb, Hf and W, for example, carbides such as TaC and TiC, or nitrides such as TiN and ZrN, form thin films of high melting point substances. By this means, the electrode substances, and particularly the alkaline earth metals that contribute to emission (electron emission), can reduce the sputtering and vaporisation due to ion bombardment.

(18) A discharge lamp that has the characteristic of being provided with;

a glass tube filled with a gas that provides a discharge
and
electron emission electrode structures that are composed of
electron emitters, provided inside the tube, that are heated by the discharge of the gas and are composed of aggregates of granules that emit thermal electrons from exposed surfaces
and
discharge focusing means that are in the close vicinity of, or in contact with, at least parts of the exposed surfaces of these electron emitters and focus the discharge on those exposed surfaces.

(19) A discharge lamp device that has the characteristic of being provided with:

a glass tube filled with gas that provides a discharge and that forms a discharge path;
electron emission electrode structures that are composed of

electron emitters, provided at the ends of the glass tube, that are heated by the discharge of the gas and are composed of aggregates of granules that emit thermal electrons from exposed surfaces;
discharge focusing means arranged in the close vicinity of, or in contact with, at least parts of the exposed surfaces of these electron emitters and focussing the discharge on those exposed surfaces;

and
a power source circuit device connected to the electron emission electrode structures to apply to a voltage

between these electrode structures.

(20) A discharge lamp device that has the characteristic of being provided with:

a discharge lamp composed of electron emission electrode structures made up of

electron emitters, provided inside a glass tube filled with gas to provide a discharge, composed of aggregates of granules heated by the discharge of the gas and emitting thermal electrons from exposed surfaces;
discharge focusing means arranged in the close vicinity of, or in contact with, at least parts of the exposed surfaces of these electron emitters and focussing the discharge on those exposed surfaces;

and
a casing housing the discharge lamp.

**[0019]** Lighting equipment that uses this discharge lamp device can be widely used for back lighting in liquid crystal display equipment, liquid crystal television, decorative equipment, etc., for reading originals in facsimile machines, etc., for exposure and for charge removal in such OA equipment as copiers, and as appliances and lighting fixtures for normal illumination.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0020]**

Figure 1 is a partially cut-away plan view showing the discharge lamp (fluorescent lap) device of a embodiment of the present invention.
Figure 2 is a vertical cross-section showing a hot cathode that is an embodiment of the present invention that is sealed into the discharge lamp (fluorescent lamp) in Figure 1,
Figure 3 is a graph showing the relationship between the discharge current (A) and the cathode fall voltage (V) of the hot cathode in Figure 2 above having an insulating body,
Figure 4 is a graph showing the relationship between the discharge current (A) and the cathode fall voltage (V) of the hot cathode in Figure 2 above not having an insulating body,
Figure 5 is an oblique view showing a hot cathode that is the electrode of another embodiment of the present invention,
Figure 6 is a graph showing the relationship between the input power during glow discharge (W) and the reciprocal of the glow-to-arc transition time $\tau$ g ($sec^{-1}$) of a fluorescent lamp using the hot cathode shown in Figure 5 above.
Figure 7 is a plan view showing a hot cathode of another embodiment of the present invention.
Figure 8 is an elevational view of the hot cathode shown in Figure 7,
Figure 9 is a plan view showing a hot cathode of another embodiment of the present invention,
Figure 10 is an elevational view of the hot cathode shown in Figure 9,
Figure 11 is a plan view showing a hot cathode of another embodiment of the present invention.
Figure 12 is an elevational view of the hot cathode shown in Figure 11,
Figure 13 is an oblique view showing a hot cathode of another embodiment of the present invention,
Figure 14 is an oblique view showing a hot cathode of another embodiment of the present invention,
Figure 15 is a partially-sectional plan view of a fluorescent lamp using the hot cathode shown in Figure 14,
Figure 16 is an oblique view showing a hot cathode of another embodiment of the present invention,
Figure 17 is a plan view showing a hot cathode of another embodiment of the present invention,
Figure 18 is (a) a plan view and (b) a vertical cross-section showing a hot cathode of another embodiment of the present invention,
Figure 19 is a partially cut-away cross-section showing a hot cathode of another embodiment of the present invention, and
Figure 20 is an oblique view showing a discharge lamp device of a embodiment of the present invention.

## PREFERRED EMBODIMENTS OF THE INVENTION

**[0021]** The following is a description, with reference to the drawings, of a embodiment of an electron emission electrode structure and a discharge lamp of the present invention.
**[0022]** Fig.1 is a partially cut-away plan showing the discharge lamp, and Fig.2 is a vertical cross-section showing the

electron emission electrode structure.

**[0023]** In Fig.1, 1 is a discharge lamp, for example, a fluorescent lamp. In lamp **1**, hot cathodes **3A** and **3A**, as the electrode structures, are positioned facing each other inside the two ends of glass tube **2**, which is composed of a translucent container that is a straight tube of external diameter, for example, from 3mm to 15mm, but here 4mm, and overall length about 300mm. At the same time, lead wires **4** and **4**, which are connected to hot cathodes **3A** and **3A**, are hermetically sealed into the respective ends.

**[0024]** Also, the inside of glass tube **2** is filled with a rare gas, for example argon, (Ar), at 20Torr and mercury, as the discharge medium. The distance between hot cathodes **3A** and **3A** is set at about 260mm. Moreover, the inner wall surface of glass tube **2** is coated with a fluorescent layer (not illustrated).

**[0025]** Also, hot cathode **3A** is composed of container **6**, which is filled with electron emitter **5**, holder **7A**, which holds container **6**, and lead wire **4**, which supports holder **7A** and at the same time forms an electrical connection. (There are cases when the lead wire is not included as part of the hot cathode.)

**[0026]** Container **6** is composed with conductive materials such as tantalum, Ta, and zirconium, Zr, as its main constituents. It is formed in the shape of a cylindrical tube with a bottom (cup) having circular base **61** and open part **62** at its ends and, at the same time, circumferential depression **63** is formed on the surface of its outer periphery.

**[0027]** Also, holder **7A** is made of nickel, and is formed in the shape of a cylindrical tube with a bottom (cup), having circular base **71** and open part **72**, that accepts container **6**. Container **6** and holder **7A** are incorporated by the rim of open part **72** of holder **7A** being inserted and locked into depression **63** of container **6**. Thus, the two are mechanically and electrically connected, and the construction is such that container **6** and holder **7A** are installed coaxially.

**[0028]** Then, electron emitter **5** is loaded into, and housed in, container **6**. Electron emitter **5** is composed of an aggregate of multiple granules **51** ... of semiconductor ceramic, in which the main constituents are particulate oxides of barium, Ba, and tantalum, Ta, of particle diameter 10μm to 500μm, and preferably 20μm to 100μm, with the addition of a small quantity of zirconium oxide, $ZrO_2$. Also, **8** is insulation composed of aluminium oxide coated on the outer surface of container **6** below depression **63** and on the inner surface of holder **7A**.

**[0029]** Moreover, lead wire **4** is welded to approximately the centre of bottom surface **71** of holder **7A**. Thus, as described above, hot cathode **3A** is composed of container **6**, holder **7A**, electron emitter **5** and lead wire **4**.

**[0030]** Apart from those mentioned above, the conductive materials that form container **6** can be at least one of tungsten, W, molybdenum, Mo, rhenium, Re, titanium, Ti, tantalum, Ta, zirconium, Zr, niobium, Nb, hafnium, Hf, nickel, Ni, or iron, Fe, or alloys of these, or the carbides, C, nitrides, N, silicides, Si, or borides, B, of these metals. Also, semiconductor substances composed of the oxides of barium, Ba, strontium, Sr, calcium, Ca or thorium, Th, may be added to the above metals.

**[0031]** Also, as other formation materials for container **6**, for example, semiconductor ceramic obtained by adding an additive (such as $Ta_2O_3$) to a mother crystal (such as $BaTiO_3$ or $BaZrO_3$) can be used. Alternatively, for example, materials composed mainly of a mixture of alkaline earth metals and metal oxides, i.e., BaO, SrO, CaO and $Ba_4Ti_2O_9$, $BaTaO_3$, $SrTiO_3$, $SrZrO_3$, and materials composed mainly of a mixture of alkaline earth metals and oxides of rare earth metals, i.e., Sc, Y, La and lanthanide, such as $BaCeO_3$, can be used.

**[0032]** Furthermore, in the case of container **6** being formed from the above alkaline earth metal, transition metal and rare earth metal materials, films of high-melting point substances, composed of a carbide or a nitride of at least one alkaline earth metal, transition metal or rare earth metal, for example, carbides such as TaC and TiC, or nitrides such as TiN and ZrN, can be formed on its surface. By this means, the dispersion and vaporisation of electrode container **6** due to ion bombardment can be reduced.

**[0033]** Also, in the case of container **6** being of insulating material, a conductive metal plate or rod may be positioned in close vicinity, and a film composed of a metal carbide or a metal nitride may be formed.

**[0034]** Also, for electron emitter **5**, apart from the above-mentioned materials, oxides such as those of barium, Ba, strontium, Sr, calcium, Ca, or materials of which the main constituents are alkaline earth metals + metal oxides, such as $Ba_4Ti_2O_9$, $BaTaO_3$, $SrTiO_3$ and $SrZrO_3$, or materials of which the main constituents are alkaline earth metals + rare earth (such as scandium, Sc, yttrium, Y, lanthanum, La and lanthanide) metal oxides can be used.

**[0035]** Moreover, in the case of electron emitter **5** being formed from the above alkaline earth metal, transition metal and rare earth metal materials, films of high-melting point substances, composed of a carbide or a nitride of at least one alkaline earth metal, transition metal or rare earth metal, for example, carbides such as TaC and TiC, or nitrides such as TiN and ZrN, can be formed on its surface, in the same way as for container **6**. By this means, the dispersion and vaporisation of electron emitter **5** due to ion bombardment can be reduced.

**[0036]** Furthermore, when manufacturing container **6** and electron emitter **5**, the two may be sintered at the same time.

**[0037]** Also, holder **7A**, can be formed from materials which contain at least one conductive metal, such as nickel, Ni, tantalum, Ta, titanium, Ti, zirconium, Zr, aluminium, Al, and tungsten, W.

**[0038]** Moreover, holder **7A** is not limited to a cover structure that holds container **6** and covers almost the entire surface of its side and bottom 61. It may also be a support, such as a frame. Furthermore, in the case of lead wire 4 being

directly connected to container **6** and performing support and electrical connection of container **6**, there is no particular requirement for holder **7A**.

**[0039]** Also, the formation of insulation **8** may be by draining off and applying a liquid in which fine particles of aluminium oxide of 0.1μm or less have been dispersed in an alcohol group solvent, and removing the solvent and moisture after application by heating for about 5 minutes in atmosphere at about100°C to 200°C. Alternatively, application may be by immersing the required parts in this liquid, pouring the liquid into the parts, etc. Moreover, insulation **8** may be formed using at least one metal oxide, such as aluminium oxide, $Al_2O_3$, silicon oxide, $SiO_2$, zirconium oxide, $ZrO_2$ and tantalum oxide, $Ta_2O_5$, or mixtures of these.

**[0040]** Then, fluorescent lamp **1** is completed by sealing hot cathodes **3A** and **3A** with the above composition inside glass tube **2** as the electrode structures. After this, lead wires **4** and **4** (or their connectors in the case of their having connectors) are connected to power source circuit system **C**, which possesses a high-frequency lighting circuit or the like. When such connection is made, current will flow to each container **6**, which is composed of a conductor and is supported by, and electrically connected to, a holder **7A**, via each holder **7A**, which is similarly composed of a conductor.

**[0041]** Then, a discharge starts and fills between hot cathodes **3A** and **3A** that take as conductors containers **6** that are positioned facing each other at the two ends of glass tube **2**, which becomes the discharge path. Ultraviolet light is generated by the rare gas and mercury in tube **2** being ionised and excited. This ultraviolet light is converted to visible light by the fluorescent layer, and this visible light is radiated externally by passing through the wall of tube **2**.

**[0042]** The discharges from hot cathodes **3A** and **3A**, which are positioned facing each other on the discharge path, are glow discharges as cold cathodes when starting. Ions that are accelerated by the high cathode fall voltage heat the entire electrode and raise its temperature, and granules **51**, ... of electron emitter **5** readily rise in temperature since, in addition to their small heat capacity, the thermal resistance between adjacent granules **51** is high. After this, when, through concentrated heating of granules **51**, the temperature is reached at which sufficient thermal electrons can be emitted, transition from glow discharge to arc discharge takes place, an arc spot is formed on granules **51**, and the electrodes act as hot cathodes.

**[0043]** The transition to arc discharge takes place after glow discharge has covered on almost the whole of conductive container **6**, with the exception of its outer surface. This arc discharge originates from exposed surface **55** of the surface layer of electron emitter **5** that is loaded into and housed in container **6**, or from the surfaces of particles **51** that are in contact with the inner wall of open part **62**. The reason for this is that it is difficult for current to flow because electron emitter **5** is a semiconductor ceramic and its electrical resistance is high. Therefore, the arc spot is formed on particles **51**, ... of electron emitter **5** that are in contact with, or in the close vicinity of, the inner wall of container **6**, which is a conductor. When the electron emitting substances in the particles **51** that form electron emitter **5** scatter and are dissipated, this arc spot shifts to adjacent particles **51**, and the discharge is maintained.

**[0044]** Also, a gap is formed between the outer surface of container **6** and the inner surface of holder **7A**, which are superposed coaxially, and the discharge would attempt to surround this part through this gap acting as a hollow cathode. However, in the present invention, the discharge is stable because the discharge does not surround the bottom of container **6** due to insulation **8** being formed on the outer surface of container **6** and the inner surface of holder **7A**.

**[0045]** As a result, by making this hot cathode **3A** the discharge focusing means, conductive container **6** does not have that action. Thus, the temperature of electron emitter **5** rises appropriately, there is no great shifting of the arc spot during lighting, and there is no flicker in the discharge; the arc spot is appropriately formed, and a stable discharge can be maintained.

**[0046]** Also, the above fluorescent lamp **1** can shorten the transition time from glow discharge to arc discharge, and reduce the cathode fall voltage. Improvement of the luminous efficacy can be devised and, at the same time, as the result of being able to reduce sputter due to ion bombardment, long life can be devised by preventing blackening of the inner wall of tube **2**.

**[0047]** Fig.3 and Fig.4 show the results of measuring the cathode fall voltages (V) in the cases of forming and not forming films of insulation **8** on the outer surface of container **6** and the inner surface of holder **7A**.

**[0048]** Compared with the case shown in Fig.4 of not forming a film of insulation **8**, in the case shown in Fig.3 of forming a film of insulation **8**, the cathode fall voltage (V) for the discharge current (A) is almost stable and hardly fluctuates. Also, the cathode fall voltage (V) for the same current value of discharge current (A) is smaller, and shortening of cathode life can be prevented.

**[0049]** Next, another embodiment of a hot cathode that is an electrode structure of the present invention will be described with reference to Fig.5. Fig.5 is an oblique view showing hot cathode **3B**. Since, apart from the holder, this is the same as in Fig.1, like reference numerals have been assigned to like parts and their descriptions have been omitted.

**[0050]** Holder **7B** shown in Fig.5 is formed in a cylindrical shape with a bottom in the same way as in the above embodiment. A pair of projecting parts **73** and **73** that protrude from the edge of opening **72** are located and formed on holder **7B**. These projecting parts, **73** and **73**, have claw-shaped tongue pieces **74** that are bent inward approximately at right angles, facing electron emitter **5**, above opening **62** of container **6**. The tips of these tongue pieces, **74** and **74**, are formed in acute-angled triangular shapes, and their two acute tips, **75** and **75**, are arranged to face exposed surface

55 of the surface layer of electron emitter 5 and to face each other with a separation between.

[0051] Consequently, by bending tip 75 of tongue piece 74 at the edge of container 6, container 6 can readily be installed in, and supported by holder 7B without causing damage to container 6, and container 6 can be prevented from shifting in the axial direction. Also, even though thermal expansion may occur in holder 7B during discharge, etc., it will support container 6 and can prevent container 6 falling off.

[0052] Projecting parts 73 and 73 are formed from holder 7B as incorporated parts. However, provided projecting parts 73 and 73 are electrically connected to holder 7B, they may also be formed separately from holder 7B and incorporated later. Also, projecting parts 73 are not limited to a pair of two; one, or three or more may also be formed.

[0053] With this hot cathode, 3B, by installing tongue pieces 74 of projecting parts 73, which become discharge focussing conductors, facing electron emitter 5 on opening 62 of container 6, glow discharges will occur at tips 75. Then, focussing of the electrical field on tips 75 takes place. The temperature rise of granules 51, ... of electron emitter 5 located in the close vicinity is accelerated, and these glow discharges can readily form arc spots on the surface of granules 51 of electron emitter 5. In this way, transition from glow discharge to arc discharge takes place in a short time, and it becomes difficult for ion sputtering to occur. Thus, blackening of the inner wall of glass tube 2 and reduction of electrode life can be prevented. Incidentally, the sharper the tips 75 of tongue pieces 74, the more readily electrical field focussing takes place. Therefore, it is desirable to make them acute angles.

[0054] Also, Fig.6 is a graph comparing input power (W) and the reciprocal of the glow-to-arc transition time [$\tau g(sec^{-1})$] for a discharge lamp of the present invention using electrode 3B in which the conductor formed is composed of tongue piece 74 of this embodiment (characteristic shown by dot mark ○) and for a prior art construction discharge lamp not provided with a conductor (characteristic shown by x mark X).

[0055] As shown in Fig.6, the lamp formed with projecting part 73 (the conductor) can achieve a large reciprocal of the glow-to-arc transition time $\tau$ g at a small input power W. Consequently, by forming projecting part 73 (the conductor), the glow-to-arc transition time can be shortened, and the time in which ion sputtering, etc., occurs can also be shortened.

[0056] Next, some other embodiments of hot cathodes that are electrode structures of the present invention will be described with reference to Fig.7 to Fig.10. Fig.7 and Fig.8 show the same hot cathode 3C, Fig.7 being a plan and Fig.8 being an elevation of Fig.7. Similarly, Fig.9 and Fig.10 show the same hot cathode 3D, Fig.9 being a plan and Fig.10 being an elevation of Fig.9. Both hot cathodes 3C and 3D have the same composition, except for the holders, as that shown in Fig.1 or Fig.5; like reference numerals have been assigned to like parts and their descriptions have been omitted.

[0057] With hot cathode 3C shown in Fig. 7 and Fig. 8 also, container 6 is housed in holder 7C. Holder 7C is formed in a cylindrical shape with a bottom, resembling the holder of hot cathode 3C shown in Fig.5, and a pair of projecting parts 73 and 73 located protruding upward from the edge of opening 72 are formed as incorporated parts. Projecting parts 73 and 73 have tongue pieces 74 constituting conductors that are bent inward at approximately right angles facing exposed surface 55 of electron emitter 5 above, but at a little distance from, opening 62 of container 6 as discharge focussing conductors. Also, tips 76 and 76, which are formed in arc shapes, of the two tongue pieces, 74 and 74, are positioned facing each other and facing, but separated from, exposed surface 55 of the surface of electron emitter 5.

[0058] Even though tips 76 and 76 of projecting parts 73 and 73 are formed in arc shapes, as shown in Fig.7 and Fig.8, electrical field focussing can occur between tips 76 and 76.

[0059] Here, with the embodiment shown in Fig.7 and Fig.8, a starting voltage test and a rapid flashing cycle test were performed for comparison using hot cathode 3C, which displays a embodiment having projecting parts 73 that constitute conductors provided with tips 76 formed in arc shapes, and a hot cathode not possessing projecting parts 73.

[0060] For the tests, fluorescent lamp 1 was used, in which the tube diameter of glass tube 2 was approximately 6mm, the distance between hot cathodes 3C and 3C was approximately 150mm, and into which mercury drop and argon gas of at approximately 100Torr were filled. Projecting parts 73 were formed using nickel plate of width approximately 1mm.

[0061] Also, in the starting test, the lamps were left for 3 hours in a location with an ambient temperature of 25°C. The voltage at transition from glow discharge to arc discharge was taken as the starting voltage. As shown in Table 1, it was found that with the lamp in which projecting parts 73 were formed, the starting-up voltage was greatly reduced.

Table 1

| Starting Voltage (kVrms) | | | | |
|---|---|---|---|---|
| Without projecting parts (conductors) | 1.75 | 1.81 | 1.83 | 1.68 |
| With projecting parts (conductors) | 1.43 | 1.56 | 1.23 | 1.37 |

[0062] Also, for the rapid flashing cycle test, a lighting circuit with characteristics of secondary release voltage approx-

imately 2.3kVrms, lamp current approximately 20mA and lamp voltage approximately 200Vrms was used. Flash lighting was repeated, taking 30 seconds of lighting and 30 seconds OFF as one cycle, and the number of times to failure of arc spot formation on the granule was measured. It was found, as shown in Table 2, that with a lamp in which projecting parts **73** (conductors) were formed the number of times to failure to light was greatly increased, and the flash life was improved.

Table 2

| Number of Times Flashed (Tens of Thousands) | | | | |
|---|---|---|---|---|
| Without projecting parts (conductors) | 5.2 | 7.5 | 9.7 | 10.4 |
| With projecting parts (conductors) | 32.3 | 40.0 | 37.8 | 45.0 |

**[0063]** Next, another embodiment of hot cathode **3D** that is an electrode structure of the present invention, shown in Fig. 9 and Fig.10, will be described.

**[0064]** With hot cathode **3C** shown in Fig.7 and Fig.8, projecting parts **73** having tongue pieces **74** were formed from, and incorporated with, holder **7C**. However, this hot cathode, **3D**, is one to which lug **77**, formed in a rod shape to constitute a conductor, is formed bent at right angles, separately from holder **7D**, is connected. The tip of rod-shaped lug **77** is caused to face exposed surface **55** of the surface of electron emitter **5** inside container **6**.

**[0065]** Even with making the discharge focussing means rod-shaped lug **77** in this way, the same action and effects can be obtained as with the above-mentioned projecting parts **73** shown in Fig.7 and Fig.8. Incidentally, if the tip of rod-shaped lug **77** is sharpened, the effect of focussing the electrical field can be further improved.

**[0066]** Also, another embodiment of a hot cathode that is an electrode structure of the present invention will be described with reference to Fig.11 and Fig.12. Fig.11 and Fig.12 show the same hot cathode **3E**, Fig.11 being a plan and Fig.12 being an elevation. Parts that are the same as in Fig.1 to Fig.10 have been assigned like reference numerals, and their descriptions have been omitted.

**[0067]** Hot cathode **3E** shown in Fig.11 and Fig.12 is provided with conductive net-like metal mesh **78**, which is either vertically and horizontally woven from metal wire or formed by punching multiple holes in a metal plate, on front opening **62** of container **6** so that it covers exposed surface **55** of the surface of electron emitter **5**, in place of the above-mentioned plate-shaped tongue pieces **73** and rod-shaped lug **77**.

**[0068]** Even with making the discharge focussing means conductive mesh **78** in this way, the same action and effects can be obtained as with the hot cathodes of the above-mentioned embodiments.

**[0069]** For this mesh, **78**, either one woven from metal wire or one produced by punching multiple holes in a metal plate can be used, employing such metals as nickel, Ni, tungsten, W, or stainless steel.

**[0070]** Moreover, other embodiments of hot cathodes that are electrode structures of the present invention will be described with reference to Fig.13 to Fig.16. Fig.13, Fig.14 and Fig.16 are oblique views showing hot cathodes **3F**, **3G** and **3H**. Fig.15 is a partially-sectioned plan of part of a fluorescent lamp, **1**, into which hot cathodes **3G** of Fig. 14 are sealed. Parts that are the same as in Fig.1 to Fig.12 have been assigned like reference numerals, and their descriptions have been omitted. Hot cathodes **3F**, **3G** and **3H** shown Fig.13, Fig.14 and Fig.16 all use conductive rod-shaped lugs of metal, etc., composed of electrode rods, as discharge focussing means.

**[0071]** For hot cathode **3F** shown in Fig.13 as an electrode rod, a through-hole (not illustrated) is formed in the centre of bottom **61** of container **6F**. Electrode rod **4A**, that constitutes a conductor composed of tungsten, W, molybdenum, Mo, titanium, Ti, tantalum, Ta, nickel, Ni, etc., is installed to pass through this hole, between granules **51**, ... of particulate electron emitter **5** that is filled into, and housed in, container **6**, and to project from approximately the centre of opening **62**. Electrode rod **4A** that constitutes this rod-shaped lug may either be the tip of lead wire **4** serving a dual purpose, or be formed as a separate entity from lead wire **4**, to which it is connected by welding, etc.

**[0072]** Incidentally, when, for example, lead wire **4** serves the dual purpose of electrode rod **4A**, it is secured in the through-hole of container **6** by welding. Also, discharge will occur more readily if the tip of electrode rod **4A** that constitutes the conductor and projects from opening **62** is formed as an acute angle.

**[0073]** By projecting the tip, that constitutes a conductor, of conductive lead wire **4**, that passes through container **6** and the centre of electron emitter **5** and serves the dual purpose of electrode rod **4A**, above opening **62** in this way, the electrical field can be focussed on this tip. Thus, granules **51**, ... of electron emitter **5** that are in contact with, or in the close vicinity of, electrode rod **4A** can be activated by raising the temperature of electrode rod **4A**. Then, an arc spot occurs on the surfaces of granules **51** that are in contact with the outer surface of electrode rod **4A** and, when electron emission from these granules **51** is complete, the arc spot shifts to the neighbouring granules **51**. Thus, an action that can stably maintain the discharge is exhibited by the arc spot gradually shifting to neighbouring granules **51**, ... .

**[0074]** Also, in hot cathode **3G** shown in Fig.14, lead wire **4** that serves the dual purpose of electrode rod **4A**, which

is composed of a rod-shaped lug in hot cathode **3F** shown in Fig.13, is in the same axial direction as the axis of container **6G**, but passes through in a position displaced from central axis **69**.

**[0075]** That is to say, lead wire **4** that serves the dual purpose of electrode rod **4A** is on the central axis of container **6G** outside container **6G** on the base end side. However, bent section **41** is formed in the vicinity of, and outside, bottom **61** of container **6G**. Thus, the composition is such that the part that constitutes the conductor and projects from inside container **6G** and from opening **62** is positioned offset from central axis **69** of container **6G**.

**[0076]** Also, fluorescent lamp **1A** is completed by sealing hot cathodes **3G** and **3G** into the ends of glass tube **2**, as shown in Fig.15. With these hot cathodes **3G**, a current flows in conductive electrode rod **4A** and container **6G** when switched ON, and a discharge takes place between hot cathodes **3G** that face each other. At this time, electrode rod **4A** in container **6G** is closer to the inner wall of container **6G** than if it were on central axis **69** of container **6G**. Therefore, the temperatures of electrode rod **4A** that constitutes a conductor and of container **6G**, which together form hot cathode **3G**, can be raised, and the activation of particles **51**, ... can be increased by the temperature rise of electron emitter **5** that accompanies this. Thus, transition from glow discharge to arc discharge is good.

**[0077]** Also, even with electrode rod **4A** being in an off-set position and not in a position on the central axis of container **6G**, since generation of the arc spot shifts to particles **51**, ... of electron emitter **5** that border on opening **62**, an appropriate arc discharge can be produced with hardly any effect on the emission properties from the slight displacement. In this lamp **1A**, lead wires **4** that are sealed into the ends of tube **2** are sealed in approximately on the central axis of tube **2**. Therefore, the sealed parts do not cause any lumps of glass, unevenness, etc., due to displacement of lead wires **4** and there is no occurrence of cracks.

**[0078]** Incidentally, it has been confirmed that, when granules **51** of particulate electron emitter **5** in the vicinity of the inner wall of container **6G** become unable to emit thermal electrons through having used up their electron-emitting substance, other granules **51**, that are adjacent in the circumference direction of the inner wall of container **6G**, will emit thermal electrons. Thereafter, the electron-emission function gradually shifts to granules **51** that are adjacent in this inner wall circumferential direction.

**[0079]** Also, when the relationship between mean input power W and the reciprocal of glow-to-arc transition time $\tau$ g of fluorescent lamp **1A** that uses hot cathodes **3G** and **3G** is compared, it is almost the same result as that shown in Fig. 6. However, the lamp in which electrode rods **4A** are formed projecting from containers **6G** can achieve a greater reciprocal of glow-to-arc transition time $\tau$ g at a smaller input power. Consequently, by forming projecting electrode rods **4A**, the glow-to-arc transition time can be shortened, and thus the time during which ion sputtering, etc., occurs is reduced.

**[0080]** Furthermore, hot cathode **3H** of another embodiment will be described with reference to Fig.16. Fig.16 is an oblique view of a hot cathode. With hot cathode **3H**, shown in Fig.16 as an electrode, electrode rod **4A** that serves the dual purpose of lead wire **4** is positioned along the central axis of container **6H** and, at the same time, branch connection **42** is formed in lead wire **4**. Multiple, for example four, rod electrodes **4B** are provided from branch connection **42** in branch-like form approximately parallel to electrode rod **4A**. All their tips project from opening **62** as rod-shaped lugs.

**[0081]** Incidentally, the positioning of electrode rods **4A** and **4B**, ..., which are formed as rod-shaped lugs constituting conductors, may be with electrode rods **4B**, ... equally spaced, or unequally spaced, taking electrode rod **4A** as the centre. Moreover, the number of these branches may be one or more.

**[0082]** Also, by providing multiple electrode rods **4A** and **4B**, ... that constitute conductors in this way, the temperature rise is made more vigorous, not only in the environs of electrode rods **4A** and **4B**, ..., but also in the environs of their tips, and an emission domain is formed over the whole area of electron emitter **5**. Thus, the glow-to-arc transition time can be shortened, and the time during which ion sputtering, etc., occurs can be reduced. Also, after using up granules **51**, ... of electron emitter **5** in the environs of one electrode rod **4A** or **4B**, the arc spot is formed in the environs of another electrode rod **4A** or **4B**. Thus, life becomes longer.

**[0083]** Also, Fig.17 to Fig.19 show other embodiments of hot cathodes **3J** to **3L** as electrode structures. In the drawings, like reference numerals have been assigned to parts that are the same as in Fig.2, and their descriptions have been omitted. The configurations of the respective containers of hot cathodes **3J** to **3L** shown in Fig.17 to Fig.19 differ from those shown in Fig.2 to Fig.16.

**[0084]** Fig. 17 is a plan view of conductive hot cathode **3J**. Viewed from above, while the outer circumference of container **6J** shown in hot cathode **3J** forms a circle, the peripheral configuration of the inner wall of opening **62**, that houses granules **51**, ... of electron emitter **5**, is formed as wave-shaped uneven periphery **63**.

**[0085]** Also, in a discharge lamp into which these hot cathodes are sealed, because the inner wall of container **6J** is indented, the length of the inner wall periphery can be made longer than if it were merely a circle concentric with the outer wall. That is to say, the area with which granules **51**, ... of electron emitter **5** are in contact can be made larger. Thus, when the lamp is ON, the absolute number of granules **51**, ... of electron emitter **5** that are in contact with, or are in the close vicinity of, uneven periphery **63** of uneven inner wall **62** of conductive container **6J** becomes larger.

**[0086]** Also, when this discharge lap is ON, an arc spot is generated in granules **51** of electron emitter **5** that are in contact with, or are in the close vicinity of, uneven inner wall **62** of container **6**, which is the conductor, and moreover

from granules **51** on the surface. Thus, when the electron-emitting material in granules **51** is dispersed and exhausted, the arc spot shifts to adjacent particles **51** and the discharge is maintained.

**[0087]** As a result, as well as discharge initiation being simple, the arc spot will not shift much during lighting, and a stable discharge, in which there is no discharge flicker, can be maintained. Also, the above lamp can shorten the transition time from glow discharge to arc discharge, and can reduce the cathode fall voltage. Thus, improvement of luminous efficacy can be devised and, at the same time, as the result of being able to reduce sputtering clue to ion bombardment, blackening of the inner wall of lamp **2** can be prevented and long life can be designed.

**[0088]** Also, Fig.18 shows another hot cathode **3K**; (a) is a plan and (b) is a vertical cross-section.

**[0089]** Hot cathode **3K** has an incorporated circular projection from the circular bottom of container **6K** toward the centre of the opening. Inside container **6K** there is ring-shaped depression **65**, and granules **51**, ... of electron emitter **5** are loaded in a ring shape into depression **65**. In this case, central projection **64** is also a conductor, and the arc spot that is the origin of discharge can be caused to be generated on the entire lengths of the peripheries of inner wall **62** and projection **64**. Thus, the same operational effect as in the above-mentioned embodiments can be displayed.

**[0090]** With hot cathodes **3J** and **3K** shown in Fig.17 and Fig.18 the overall lengths of the inner wall peripheries of containers **6J** and **6K** are longer than simple circles. Thus, these hot cathodes have the advantage that arc discharge can be maintained because arc spots generate readily in those parts and thermal electron emission is performed over long periods.

**[0091]** Also, the shapes of containers are not limited to right circles. They may also be elliptical, or polygonal, such as regular square-shaped or oblong-shaped. Moreover, the shapes of the inner wall peripheries are not limited to the wave-shaped indentations formed in the right circular inner wall shown in the drawing. They may also be wave-shaped, saw-toothed, etc., indentations formed in elliptical or polygonal, such as regular square-shaped or oblong-shaped, inner walls. Furthermore, the shape of the above-mentioned central projection **64** also is not limited to right circular. It may be elliptical or polygonal, and it may be formed as one or multiple projections, either separate or linked together, and in addition, its periphery may be indented.

**[0092]** Incidentally, when this is expressed numerically, for example in the case of a circular container, the relationship should be

$$L > 2(\pi \cdot S)^{1/2},$$

where **L** is the inner wall peripheral length of the depression of the container, and **S** is the projected area of the opening. In short, the longer the peripheral length of the container inner wall can be made, the better.

**[0093]** Also, with hot cathode **3L** shown in Fig.19, the shape of container **6L** differs from those described previously. That is to say, all those previously described were formed as equal-diameter cylinders, but this container **6L** is formed with opening **62** of greater diameter than bottom surface **61**.

**[0094]** With container **6L**, formed in a trumpet shape with opening **62** of large diameter in this way, the outer periphery of container **6L** and opening **72** of holder **7L** are in a state of contact, and the gap apparently disappears. Thus, passage of the discharge through the gap to surround the air space between the two can be prevented.

**[0095]** Also, particulate electron emitter **5** composed of a large quantity of granules **52**, ... and **53**, ... can be placed on the exposed surface at the front where arc spots that are the origins of discharges readily form. By this means, with discharge lamps into which these hot cathodes **3L** are sealed the arc discharge is stable, no flickering occurs during lighting, and life can be lengthened.

**[0096]** Furthermore, the inventors of the present invention studied the discharge lamps disclosed in the above embodiments. They found that, through the relationship between the pressure (Torr) of the sealed-in rare gas, the mean particle diameter **D** (μm) of granules **51** of particulate electron emitter **5** and the discharge current $I_L$ (mA) the transition from glow discharge to arc discharge could be accelerated and, at the same time, the arc discharge could be stabilised over long periods.

**[0097]** Namely, fluorescent lamps were produced in the following way. Hot cathodes **3B** and **3B**, shown in Fig.5, were placed in opposition at an inter-electrode distance of approximately 260mm at the two ends of straight tubular glass tubes **1** of external diameter approximately 4mm and overall length approximately 300mm, such as shown in Fig.1 for example. A fluorescent layer was formed on the inner surfaces of tube **1**, and argon, Ar, as the rare gas, together with mercury, Hg, droplet were sealed inside. The sealing-in pressure and the mean particle diameters of granules **51** of granular electron emitter **5** were varied.

**[0098]** Electron emitters **5** made up of aggregates of granules **51**, ... of particle diameter 10μm to 100μm were housed in bottomed cylindrical containers **6** that composed these hot cathodes **3B**. Also, containers **6** and granules **51**, ... of electron emitters **5** were formed from a material of which the main constituents were the oxides of barium, Ba, and tantalum, Ta, with a small quantity of zirconium oxide, $ZrO_2$. To improve anti-sputter capability, thin films of tantalum car-

bide, TaC, were coated on their surfaces.

**[0099]** Moreover, the variations made in the pressure of the gas sealed inside tube **1**, the mean particle diameter of granules **51** of electron emitter **5**, and the discharge current are the results shown in Tables 3 ~ 5. Incidentally, the mean particle diameter was found from the arithmetical mean of the particle distribution. Also, for the gas pressure, in the case of including mercury vapour at about room temperature in the total pressure of the sealed in gas, for example in the total pressure of approximately 70Torr for argon, Ar,/neon, Ne, the sealed-in gas pressure became 70Torr.

Table 3

| No. | Granule Diameter (μm) | $I_L$ (mA) | Ar Pressure (Torr) | Blow-to-Arc Tansition | Flash Test $10_sON$ $\cdot 10_sOFF$ | Arc Discharge During Life | $\frac{P \cdot I_L}{D}$ |
|---|---|---|---|---|---|---|---|
| 1 | 45 | 10 | 10 | × | × | × | 2 |
| 2 | | | 20 | × | × | × | 4 |
| 3 | | | 30 | ○ | × | × | 7 |
| 4 | | | 50 | ○ | ○ | ○ | 11 |
| 5 | | | 70 | ○ | ○ | ○ | 16 |
| 6 | | | 100 | ○ | ○ | ○ | 22 |
| 7 | | 20 | 10 | × | × | × | 4 |
| 8 | | | 20 | ○ | × | × | 9 |
| 9 | | | 30 | ○ | ○ | ○ | 13 |
| 10 | | | 50 | ○ | ○ | ○ | 22 |
| 11 | | | 70 | ○ | ○ | ○ | 31 |
| 12 | | | 100 | ○ | ○ | ○ | 44 |
| 13 | | 30 | 10 | ○ | × | × | 7 |
| 14 | | | 20 | ○ | ○ | ○ | 13 |
| 15 | | | 30 | ○ | ○ | ○ | 20 |
| 16 | | | 50 | ○ | ○ | ○ | 33 |
| 17 | | | 70 | ○ | ○ | ○ | 47 |
| 18 | | | 100 | ○ | ○ | ○ | 67 |
| 19 | | 50 | 10 | ○ | ○ | ○ | 11 |
| 20 | | | 20 | ○ | ○ | ○ | 22 |
| 21 | | | 30 | ○ | ○ | ○ | 33 |
| 22 | | | 50 | ○ | ○ | ○ | 56 |
| 23 | | | 70 | ○ | ○ | ○ | 78 |
| 24 | | | 100 | ○ | ○ | ○ | 111 |
| 25 | | 70 | 10 | ○ | ○ | ○ | 16 |
| 26 | | | 20 | ○ | ○ | ○ | 31 |
| 27 | | | 30 | ○ | ○ | ○ | 47 |
| 28 | | | 50 | ○ | ○ | ○ | 78 |
| 29 | | | 70 | ○ | ○ | ○ | 109 |
| 30 | | | 100 | ○ | ○ | ○ | 156 |

Table 4

| No. | Granule Diameter (μm) | $I_L$ (mA) | Ar Pressure (Torr) | Blow-to-Arc Transition | Flash Test $10_s$ON $\cdot 10_s$OFF | Arc Discharge During Life | $\frac{p \cdot I_L}{D}$ |
|---|---|---|---|---|---|---|---|
| 31 | 75 | 10 | 10 | × | × | × | 1 |
| 32 | | | 20 | × | × | × | 3 |
| 33 | | | 30 | × | × | × | 4 |
| 34 | | | 50 | ○ | × | × | 7 |
| 35 | | | 70 | ○ | × | × | 9 |
| 36 | | | 100 | ○ | ○ | ○ | 13 |
| 37 | | 20 | 10 | × | × | × | 3 |
| 38 | | | 20 | × | × | × | 5 |
| 39 | | | 30 | ○ | × | × | 8 |
| 40 | | | 50 | ○ | ○ | ○ | 13 |
| 41 | | | 70 | ○ | ○ | ○ | 19 |
| 42 | | | 100 | ○ | ○ | ○ | 27 |
| 43 | | 30 | 10 | × | × | × | 4 |
| 44 | | | 20 | ○ | × | × | 8 |
| 45 | | | 30 | × | ○ | ○ | 12 |
| 46 | | | 50 | ○ | ○ | ○ | 20 |
| 47 | | | 70 | ○ | ○ | ○ | 28 |
| 48 | | | 100 | ○ | ○ | ○ | 40 |
| 49 | | 50 | 10 | ○ | × | × | 7 |
| 50 | | | 20 | ○ | ○ | ○ | 13 |
| 51 | | | 30 | ○ | ○ | ○ | 20 |
| 52 | | | 50 | ○ | ○ | ○ | 33 |
| 53 | | | 70 | ○ | ○ | ○ | 47 |
| 54 | | | 100 | ○ | ○ | ○ | 67 |
| 55 | | 70 | 10 | ○ | × | × | 9 |
| 56 | | | 20 | ○ | ○ | ○ | 19 |
| 57 | | | 30 | ○ | ○ | ○ | 28 |
| 58 | | | 50 | ○ | ○ | ○ | 47 |
| 59 | | | 70 | ○ | ○ | ○ | 65 |
| 60 | | | 100 | ○ | ○ | ○ | 93 |

Table 5

| No. | Granule Diameter (μm) | $I_L$ (mA) | Ar Pressure (Torr) | Glow-to-Arc Transition | Flash Test $10_sON \cdot 10_sOFF$ | Arc Discharge During Life | $\frac{p \cdot I_L}{D}$ |
|---|---|---|---|---|---|---|---|
| 61 | 105 | 50 | 2 | × | × | × | 1 |
| 62 | | | 5 | × | × | × | 2 |
| 63 | | | 10 | × | × | × | 5 |
| 64 | | | 20 | ○ | ○ | ○ | 10 |
| 65 | | | 50 | ○ | ○ | ○ | 24 |
| 66 | | 100 | 2 | × | × | × | 2 |
| 67 | | | 5 | × | × | × | 5 |
| 68 | | | 10 | ○ | ○ | ○ | 10 |
| 69 | | | 20 | ○ | ○ | ○ | 19 |
| 70 | | | 50 | ○ | ○ | ○ | 48 |
| 71 | | 150 | 2 | × | × | × | 3 |
| 72 | | | 5 | ○ | × | × | 7 |
| 73 | | | 10 | ○ | ○ | ○ | 14 |
| 74 | | | 20 | ○ | ○ | ○ | 29 |
| 75 | | | 50 | ○ | ○ | ○ | 71 |
| 76 | | 200 | 2 | × | × | × | 4 |
| 77 | | | 5 | ○ | ○ | ○ | 10 |
| 78 | | | 10 | ○ | ○ | ○ | 19 |
| 79 | | | 20 | ○ | ○ | ○ | 38 |
| 80 | | | 50 | ○ | ○ | ○ | 95 |
| 81 | | 250 | 2 | × | × | × | 5 |
| 82 | | | 5 | ○ | ○ | ○ | 12 |
| 83 | | | 10 | ○ | ○ | ○ | 24 |
| 84 | | | 20 | ○ | ○ | ○ | 48 |
| 85 | | | 50 | ○ | ○ | ○ | 119 |

**[0100]** Here, for transition from glow discharge to arc discharge, the case of exceeding 1 second was taken as mark X (bad) and the case of 1 second or less was taken as mark o (good). For the flashing test, 10 seconds ON and 10 seconds OFF was repeated, and the case of a life of less than 100,000 times was taken as mark X, while a life of

100,000 times or more was taken as mark o. For arc discharge during life, the case of discharge from other than granules **51** although barium, Ba, remained on the surfaces of particles **51** was taken as mark X, and the case of discharge from granules **51** while barium, Ba, remained in granules **51** was taken as mark o.

**[0101]** Also, in the case of the relationship

$$P \times I_L / D \geqq 10$$

where the rare gas sealed-in pressure is taken as **P** torr, the mean particle diameter of granules **51** of particulate electron emitter **5** as **D** μm, and the discharge current as $I_L$ mA, transition from glow discharge to arc discharge can be accelerated. At the same time, the arc discharge can be stabilised, and blackening of the inner wall of glass tube **1** and shortening of life can be prevented.

**[0102]** Moreover, according to the above expression, the higher the sealed-in gas pressure, the better. However, the starting voltage will become higher and the luminous efficacy will reduce if the specified sealed-in gas pressure becomes higher. Therefore, here are also limits to the sealed-in gas pressure in line with the specifications. Incidentally, even when tests were carried out with other sealed-in gases, for example, a mixture gas of sodium, Na, neon, Ne, and argon, Ar, a mixture gas of barium, Ba, and argon, Ar, and a mixture gas of barium, Ba, and xenon, Xe, it was possible to obtain the same results.

**[0103]** Furthermore, in cases of using mixtures of differing particle diameter distributions for particulate electron emitter **5** as the electron emission electrode structure, discharge lamps were obtained in which light adjustment could readily be carried out.

**[0104]** That is to say, multiple thermal electron emitters **5** having two, large and small, peak values of mean particle diameter distribution made up of semiconductor ceramic, such as barium and tantalum oxide, $BaTaO_3$, were loaded into, and housed in, for example, containers **6L** of hot cathodes **3L** shown in Fig.19. This particle diameter distribution was made up of a mixture of comparatively large diameter granules **52**, ... having a mean particle diameter peaking at approximately 100μm and comparatively small diameter granules **53**, ... having a mean particle diameter peaking at approximately 30μm. The particle size distribution was in the range of 10μm to 150μm.

**[0105]** Then, the fluorescent lamps into which these hot cathodes **3L** and **3L** were sealed were lit via a dimming circuit device (not illustrated). When the lamp current for the case of not performing dining was about 30mA, out of the electron emitter **5** housed in container **6L**, arc spots originated on 1 or 2 comparatively large diameter granules **52**, ... of particle diameter approximately 100μm, and maintained a stable discharge. However, with the comparatively small diameter granules **53**, ... of particle diameter approximately 30μm, arc spots originated straddling several particles. Therefore, the thermal accumulator structure was destroyed and the arc spots readily shifted to other granules. Consequently, effectively, the stable arc spots originated on comparatively large diameter granules **52** of particle diameter approximately 100μm.

**[0106]** Also, when, for dimming, the current was altered and these lamps were lit by about 5mA, arc spots originated on 1 ~ 2 comparatively small diameter granules **53**, ... of particle diameter approximately 30μm, and maintained a stable discharge. However, with the comparatively large diameter granules **52**, ... of particle diameter approximately 100μm, because their thermal capacities were comparatively large compared with the comparatively small diameter granules **53**, ... of particle diameter approximately 30 μm, sufficient heat for thermal electron emission could not be obtained with a current as low as approximately 5mA. Consequently, effectively, it came about that stable arc spots originated on comparatively small diameter granules **53** of approximately 30μm for which electron emission was good.

**[0107]** Therefore, with discharge lamps that use mixed electron emitters of differing particle diameter distributions in this way, it is possible to cause origination of arc spots by raising the temperature of the electron emitter that has a peak particle diameter corresponding to the lamp current. Consequently, by applying this to discharge lamps that perform light adjustment by controlling the current in answer to the current value, it is possible to carry out stable arc discharge and dimming.

**[0108]** Incidentally, this particle diameter distribution peak value is not limited to mixtures of two types; there may be three or more types. However, the effect is greater when the difference between adjacent mean particle diameter values is 1.5 or more.

**[0109]** Furthermore, Fig.20 is an oblique view showing an embodiment of discharge lamp device **9** concerned in the present invention. In Fig.20, a casing **91** is shown. Reflector mirror **92**, supporting members **93** and **93** (one of which is not shown), such as sockets, that support fluorescent lamp **1**, and power source circuit device **C** are provided inside casing **91**.

**[0110]** This discharge lamp device, **9**, can be used for the backlight of a liquid crystal display device or for a facsimile original reader. Since, as stated above, the light emission characteristic of fluorescent lamp **1** is improved and it has long life, the light emission characteristics of the above devices also will be increased, and their maintenance will be simpler because lamp **1** will not require replacing for long periods.

**[0111]** Incidentally, the present invention is not limited to the embodiments stated above. For example, the electrode structures of the above embodiments are composed by housing particulate electron sitters in containers. However, electrode structures may also be produced by placing particulate emitters in sintering containers, and connecting lead wires, etc., to the bodies that are removed from these containers after sintering. Containers support electrode structures inside tubes and act as means for electrical connection with lead wires, but they are not indispensable.

**[0112]** Also, the containers that compose the hot cathodes that are the electrode structures are described above as being made of metals having conductivity. Nevertheless, they may also be made from semi-insulating so-called conductive ceramics, in which semiconductor ceramic substances are mixed with conductive metals, or they may be made of semiconductor ceramic substances or insulating materials, with conductivity given to their surfaces. In short, provided it is something that acts as a good conductor when switched ON and satisfactorily performs passage of current to the electron emitter housed inside it, it may be applied.

**[0113]** Moreover, discharge lamps are not confined to fluorescent lamps. They may be applied in other discharge lamps, such as ultraviolet emission lamps. Also, the discharge lamps may be rare gas light-emitting lamps, and there is no need to load in mercury as a discharge medium. Moreover, the configuration of the glass tubes is not limited to straight tube-shaped tubes. Lamps may use curved tubes, such as U-shaped, W-shaped and ring-shaped, or they may use board-shaped tubes.

**[0114]** Also, the number of electrodes provided in one discharge lamp is not limited to a pair (two). A lamp may have three or more electrodes, and it goes without saying that they can be applied to lamps in which part of the electrode is provided on the outside surface of the tube.

**[0115]** Furthermore, the discharge lamp device is not limited to the composition of the embodiment. It is possible to vary the shape, construction, etc., in many ways.

Also, the casing that houses the lamp, etc., is not limited to the box-shaped casing shown here. The casings include board-shaped housings on which the lamp, its supporting members, etc., are mounted in exposed fashion. Moreover, the power source circuit device for lighting and the reflector mirror may be provided separately from the discharge lamp device, and are not indispensable items.

## POSSIBILITIES FOR INDUSTRIAL USE

**[0116]** When using the electron emission electrode structures concerned in the present invention in the above way, a rapid release of thermal electrons is possible when starting the discharge lamp, and the glow-to-arc transition time is accelerated. Furthermore, it is possible to provide long-life electrodes that can prevent blackening of the inner wall and shortening of the life of the lamp tube. For this reason, with lighting devices which use this lamp, the light emission property and life property can be improved and, at the same time, maintenance work can be simplified. These lamps can be widely used for back-lighting for liquid crystal display devices and liquid crystal televisions; in OA equipment such as for original reading in facsimile machines and for exposure and discharge in copiers, and in appliances, lighting fixtures, etc., for normal illumination.

## Claims

1. An electron emission electrode structure comprising:

   an electron emitter heated by a discharge, composed of an aggregate of electron emission particles or granules emitting thermal electrons from an exposed surface thereof;
   and
   a discharge focussing means which is in the close vicinity of, or in contact with, at least a part of the exposed surface of this electron emitter and focuses the discharge on the exposed surface.

2. An electron emission electrode structure comprising:

   an electron emitter heated by a discharge, composed of an aggregate of electron emission particles, emitting thermal electrons from the exposed surface thereof;
   a discharge focussing means which is in the close vicinity of, or in contact with, at least a part of the exposed surface of the electron emitter and focuses the discharge on the exposed surface;
   and
   a container housing the electron emitter.

3. An electron emission electrode structure comprising:

an electron emitter heated by a discharge, composed of an aggregate of electron emission particles or granules, emitting thermal electrons from the exposed surface;
and
a container which houses this electron emitter, and focuses the discharge on the exposed surface by making a part that is in the close vicinity of, or in contact with, at least one part of the exposed surface of the electron emitter a conductor.

4. An electron emission electrode structure, according to Claim 3, in which the container is made of metal.

5. An electron emission electrode structure, according to Claim 4, in which is the outer surface of the container is coated with insulation.

6. An electron emission electrode structure, according to Claim 2, in which the container being insulating or semi-insulating.

7. An electron emission electrode structure, according to Claim 6, in which the container is made of metal oxide.

8. An electron emission electrode structure, according to any of Claims 2 to 7, in which the container is supported by a holder.

9. An electron emission electrode structure, according to Claim 1, in which the discharge focussing means is a metal lug that is in contact with, or in the close vicinity of, at least a part of the exposed surface of the electron emitter.

10. An electron emission electrode structure, according to Claim 9, in which the metal lug is tongue-shaped.

11. An electron emission electrode structure, according to Claim 1, in which the discharge focussing means is a rod-shaped lug that passes through the electron emitter and projects from the exposed surface.

12. An electron emission electrode structure, according to Claim 10, in which the rod-shaped lug projects from the centre of the exposed surface.

13. An electron emission electrode structure, according to Claim 11, in which the rod-shaped lug projects off-set from the centre of the exposed surface.

14. An electron emission electrode structure, according to Claim 2, in which the discharge focussing means is a metal mesh that covers the opening side of the container.

15. An electron emission electrode structure, according to any of Claims 9 to 13, in which the discharge focussing means is formed on the container or the holder.

16. An electron emission electrode structure, according to Claim 1 or 2, in which the electron emitter granules is formed taking oxide of at least one metal out of the alkaline earth metals, the transition metals and the rare earth metals as the main constituent.

17. An electron emission electrode structure, according to Claim 1 or 2, in which films of the carbide and/or nitride of at least one metal out of the alkaline earth metals, the transition metals and the rare earth metals being formed on the surfaces of the electron emitter granules.

18. A discharge lamp comprising:

a glass tube filled with a gas that provides a discharge;
and
electron emission electrode structures that are composed of electron emitters, provided inside the tube, that are heated by the discharge of the gas and are composed of aggregates of granules that emit thermal electrons from exposed surfaces;
and

discharge focusing means that are in the close vicinity of, or in contact with, at least parts of the exposed

surfaces of these electron emitters and focus the discharge on the exposed surfaces.

19. A discharge lamp device comprising:

a glass tube filled with gas that provides a discharge and that forms a discharge path;
electron emission electrode structures that are composed of

electron emitters, provided at the ends of the glass tube, that are heated by the discharge of the gas and are composed of aggregates of granules that emit thermal electrons from exposed surfaces
and
discharge focusing means that are in the close vicinity of, or in contact with, at least parts of the exposed surfaces of these electron emitters and focus the discharge on the exposed surfaces;

and
a power source circuit device that is connected to the electron emission electrode structures and applies a voltage between these electrode structures.

20. A discharge lamp device comprising:

a discharge lamp composed of electron emission electrode structures comprising

electron emitters, provided inside a glass tube filled with gas that provides a discharge, composed of aggregates of granules that are heated by the discharge of the gas and emit thermal electrons from exposed surfaces
and
discharge focusing means that are in the close vicinity of, or in contact with, at least parts of the exposed surfaces of these electron emitters and focus the discharge on the exposed surfaces

and
a casing that houses the discharge lamp.

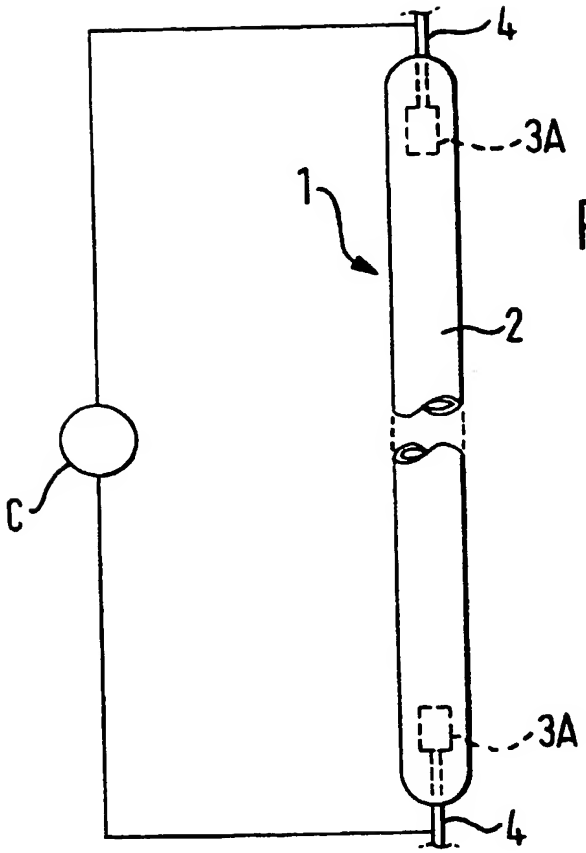



FIG.1

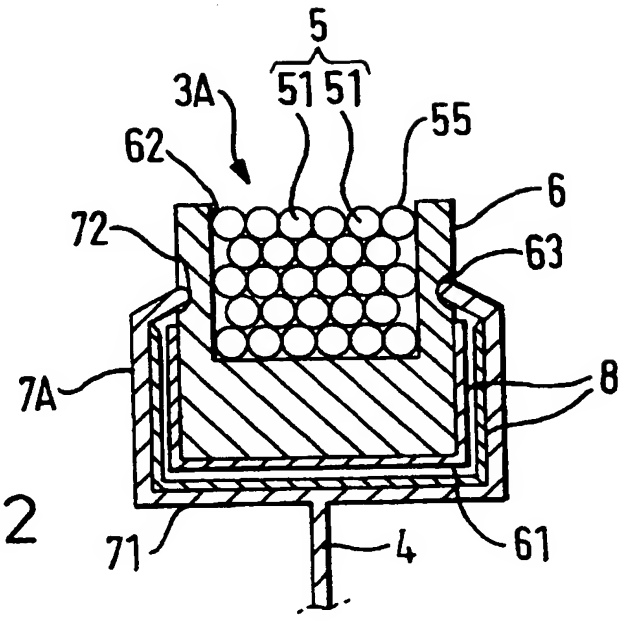



FIG.2

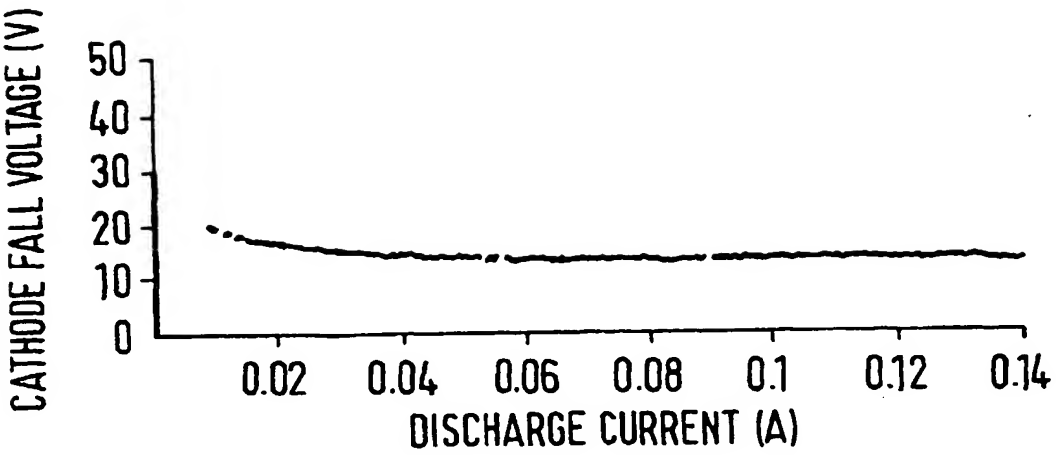

CATHODE FALL VOLTAGE (V)
50
40
30
20
10
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
DISCHARGE CURRENT (A)

FIG. 3

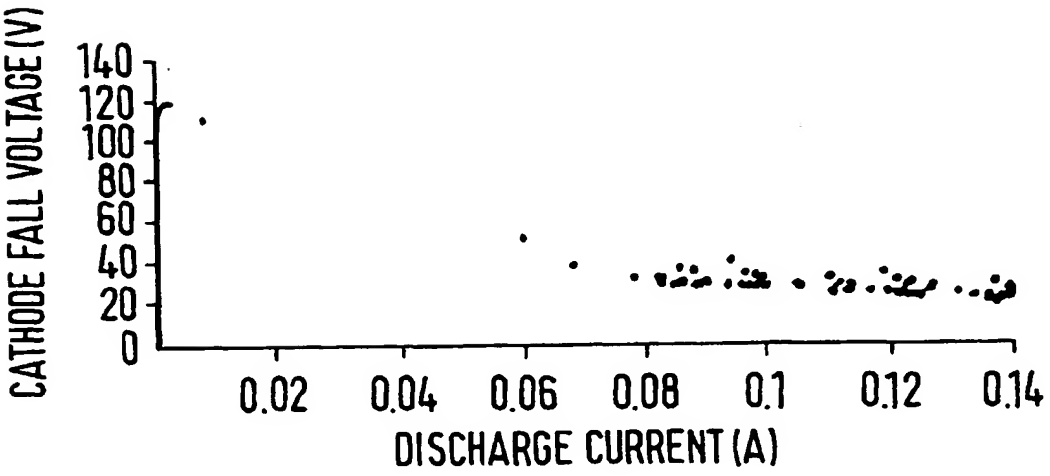

CATHODE FALL VOLTAGE (V)
140
120
100
80
60
40
20
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
DISCHARGE CURRENT (A)

FIG. 4

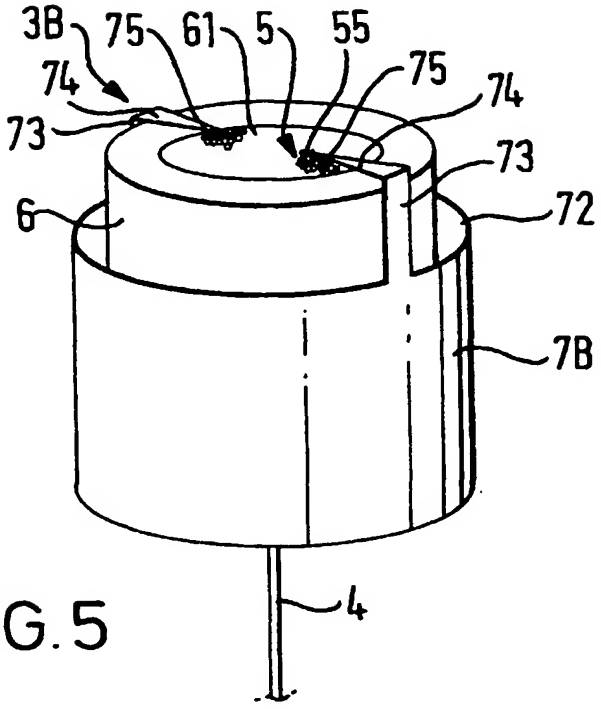

3B
75
61
5
55
75
74
74
73
73
6
72
7B
4

FIG. 5

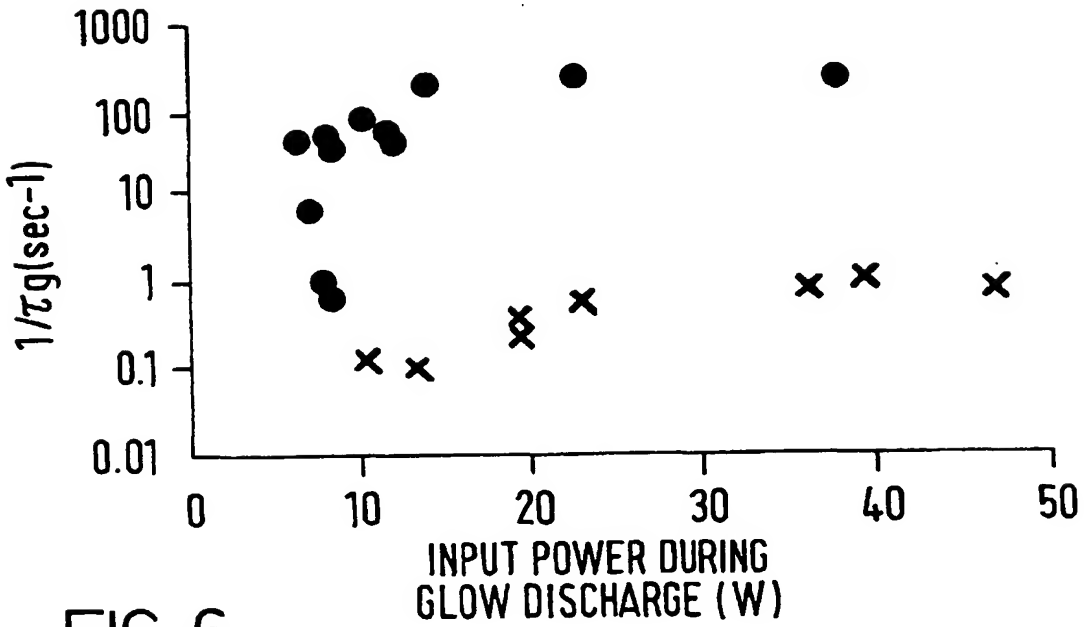

1000
100
10
1
0.1
0.01
1/τg(sec-1)
0
10
20
30
40
50
INPUT POWER DURING
GLOW DISCHARGE (W)

FIG. 6

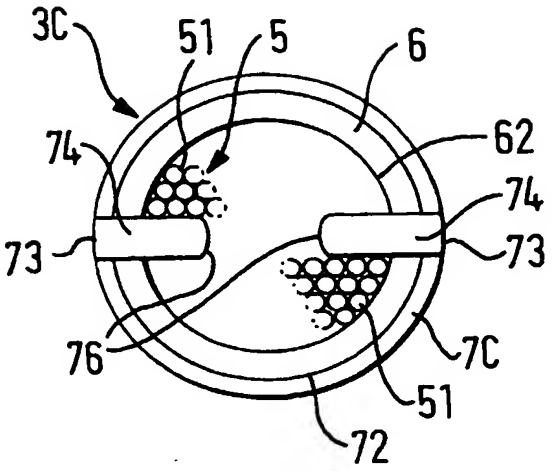



FIG. 7

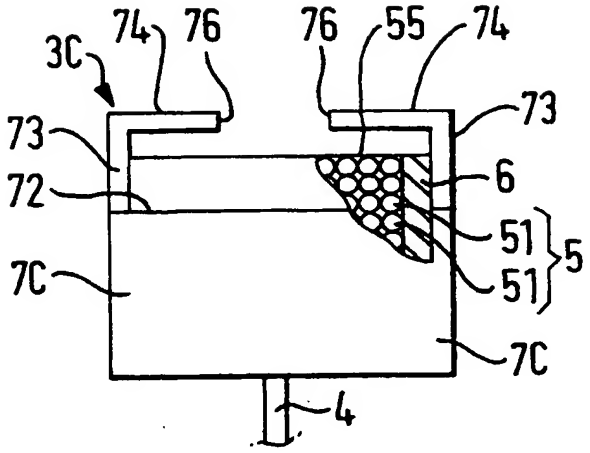



FIG. 8

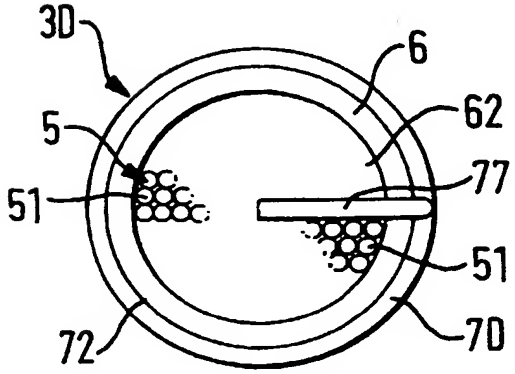



FIG. 9

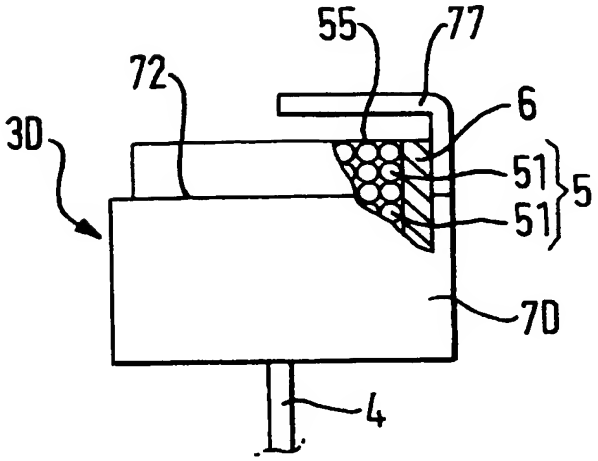



FIG. 10

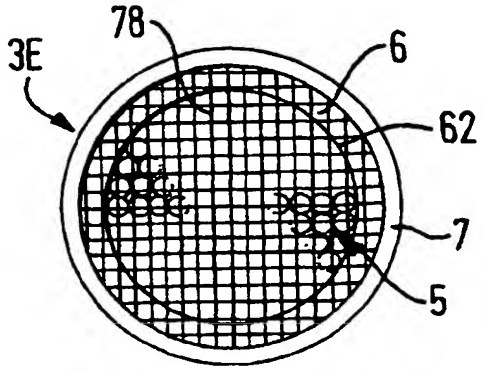



FIG. 11

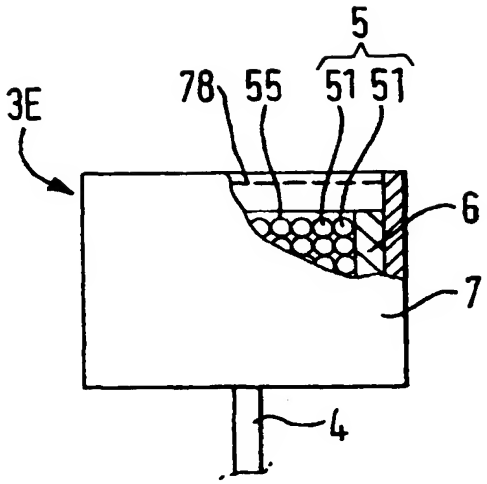



FIG. 12

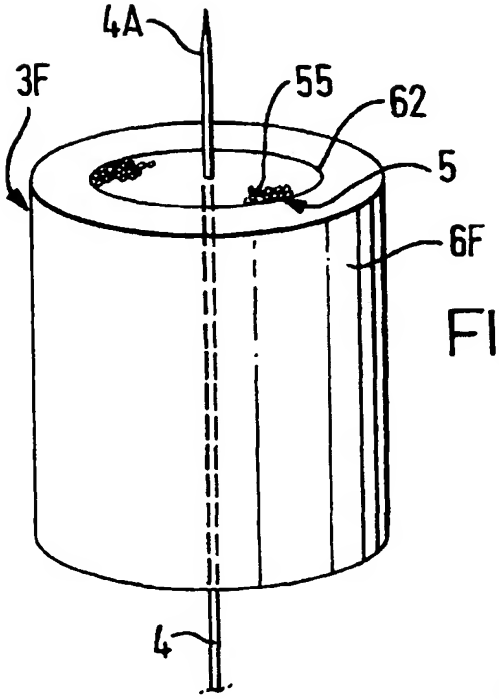
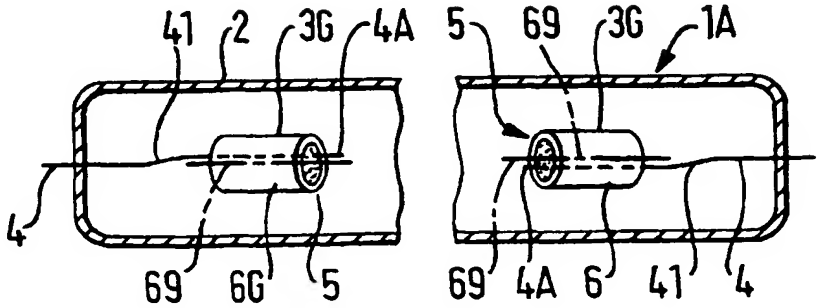



FIG. 13

FIG. 15



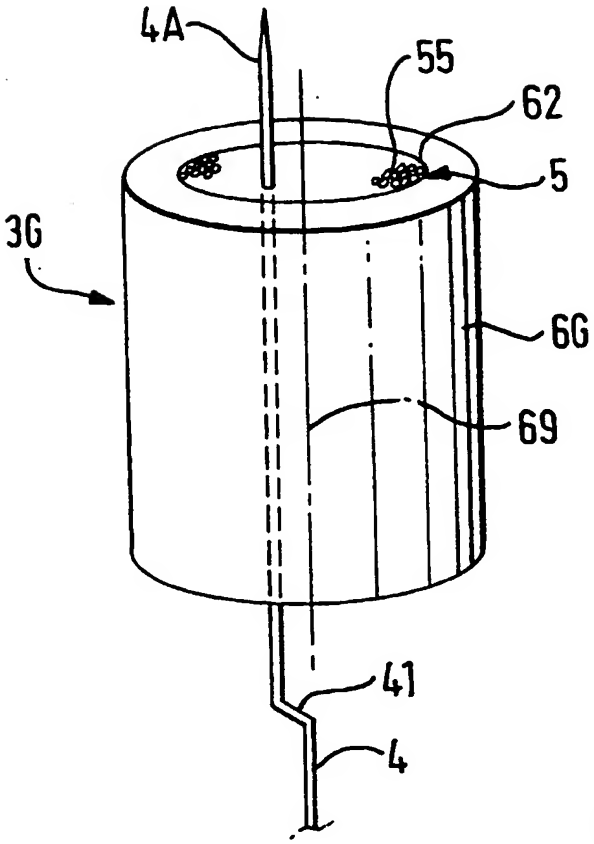



FIG.14

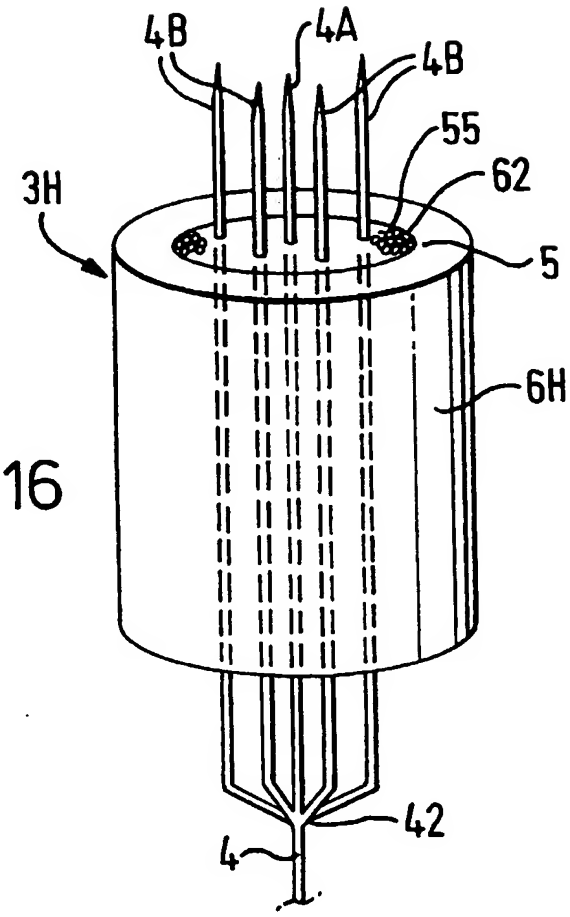



FIG.16

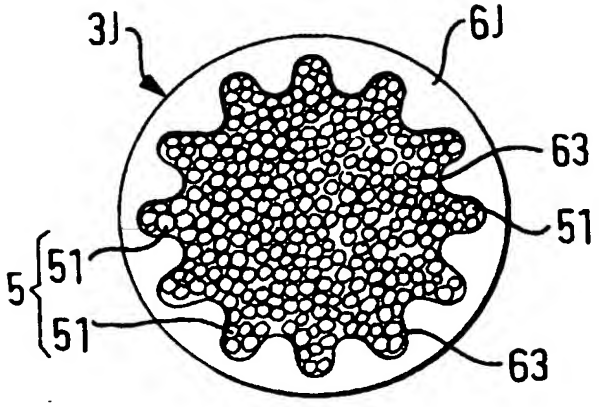



FIG. 17

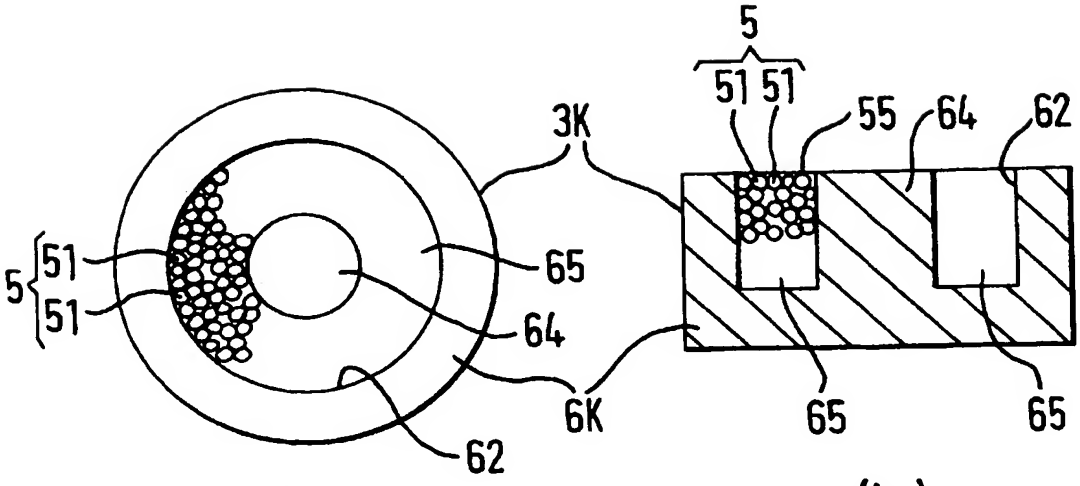



FIG. 18

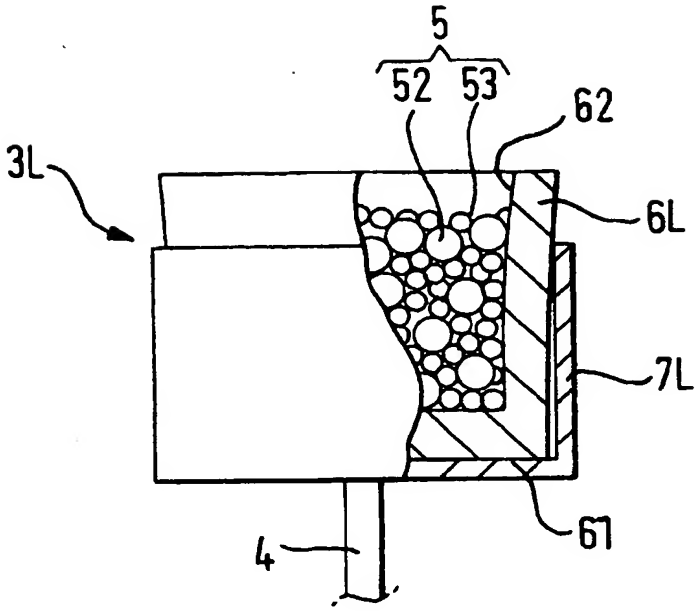



FIG. 19

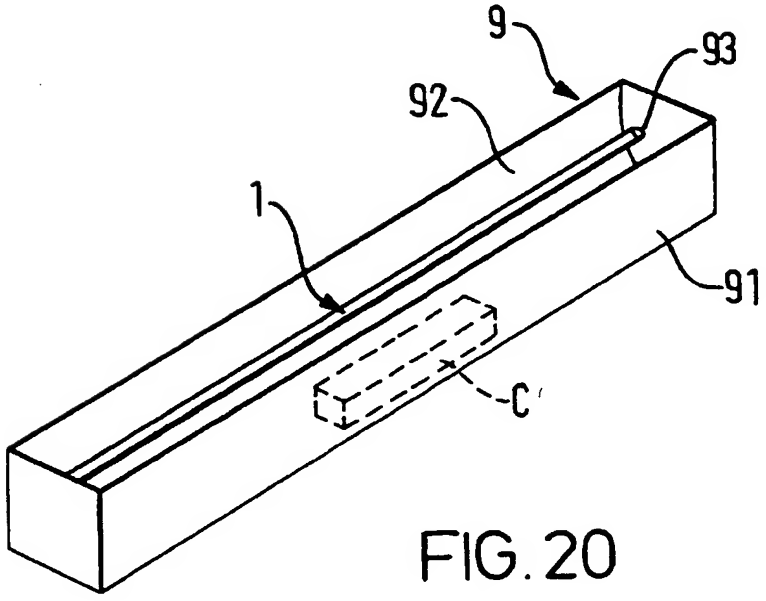



FIG. 20

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/06016

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] H01J61/067

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] H01J61/067

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1940-1996 Toroku Jitsuyo Shinan Koho 1994-1999
Kokai Jitsuyo Shinan Koho 1971-1999 Jitsuyo Shinan Toroku Koho 1996-1999

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | JP, 7-296768, A (TDK Corp.), 10 November, 1995 (10. 11. 95), Full text ; Figs. 1 to 6 | 1-4, 6-8, 16, 18-20 |
| Y | Full text ; Figs. 1 to 6 | 9, 11-12, 14, 17 |
| A | Full text ; Figs. 1 to 6 (Family: none) | 5, 10, 13, 15 |
| Y | JP, 57-50760, A (Matsushita Electric Works,Ltd.), 25 March, 1982 (25. 03. 82), Full text ; Figs. 3, 4 | 9, 11-12 |
| A | Full text ; Figs. 3, 4 (Family: none) | 10, 13, 15 |
| Y | JP, 57-21059, A (Matsushita Electric Works,Ltd.), 3 February, 1982 (03. 02. 82), Full text ; Figs. 2 to 4 (Family: none) | 14 |

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| Y | JP, 64-65764, A (TDK Corp.), 13 March, 1989 (13. 03. 89), Page 3, upper left column, line 9 to upper right column, line 7 ; Figs. 1 to 3 (Family: none) | 17 |

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